MBRAUN Whitepaper: Slot Die Coating

GUIDELINE SLOT DIE COATING

Introduction

Slot Die Coating is one of the basic methods of applying liquids to a substrate. Most simply, a coating liquid is forced out of a reservoir through a slot by pressure, and transferred to a moving substrate. In practice, the slot is significantly smaller in section than the reservoir and is oriented perpendicular to the direction of substrate movement.

Slot Die coating has many variations which can be distinguished from each other by the design of the die itself, the orientation of the die relative to the substrate, the distance from the die to the substrate (slot die coating versus extrusion coating and curtain coating), the coating structure (pattern coating versus continuous coating) and the method of how the pressure which forces liquid out of the die is generated and applied.

Slot Die coating is generally known to be coating with a die against a substrate (actually separated from the substrate by a cushion of liquid being coated). Extrusion Coating is mostly recognized as using a die with a gap between die and substrate and the liquid is self-supported as it travels from the die to the substrate.

Curtain Coating is usually recognized as using a die vertically above the substrate at some distance, usually with wires or fixed supports on the edges of the liquid curtain to keep the coating liquid in a flat bubble shape from collapsing as it travels down to the substrate.

Practical considerations for use of slot dies as a coating method are geared to the quality needs of the coated product. These needs include acceptable performance, uniformity of coating thickness, absence of point or line defects and a uniform surface finish with the desired characteristics. As is the case with many manufacturing processes, high efficiency and productivity are usually key driving forces.

Slot Die coating helps maintain a high level of cleanliness, as the entire liquid flow path can be sealed against the environment, until the moment the liquid meets the substrate. Wear in a Slot Die system is very low compared to most other coating methods, further reducing contamination of a coated product.

Uniformity and Quality of coated products demand:

- coating liquids of appropriate composition and flow characteristics for the substrate
- consistent coating liquid – constant in composition, viscosity, and temperature
- suitable pretreatment process (UV-Ozone, plasma, excimer)
- consistent substrate (thickness, flatness, surface properties, etc)
- uniform liquid handling and pressure feeding
- mechanically accurate and reproducible die support
- uniform substrate speed and tension at the point of coating
- appropriate curing after the coating
- environmental cleanliness (absence of airborne particles)
- methods, procedures, and measurements, to allow control of important variables
- design, precision and right choice of sub-components

Profile Uniformity

Profile of a coated layer relates to the deviation from the average thickness both in the cross substrate direction, and in the down substrate directions. Cross Substrate profile is generally controlled by the slot die flow design. Down Substrate or machine direction profile is generally controlled by uniformity

of substrate speed and substrate tension, uniformity of feed pressure to the slot die and mechanical stability and freedom from vibration.

Cross Substrate Profile

One branch of strategy to yield a uniform cross substrate profile is using a control system of so called ñcontinuousò measurement of profile (normally a scanning sensor which describes a ñsaw toothò pattern of measurement of the coated material along its length). Software interprets the measurements and feeds back a control action to a slot die with a number of thickness control points across the width of the die. The control action then ñfixesò the profile for the next length of coating. For instance, a measured thick lane of coating 2 inches in from one side of the substrate causes a control action to reduce the thick lane by redirecting the extra coating liquid to ñsomewhere elseò across the substrate. The ultimate goal of this type of high performance measurement/control system is to achieve a steady state, non-changing setting of the profile adjustment ñboltsò, once a good profile has been attained.

Another method is to use the same ñsawtoothò scanning, then operator experience and technique is employed to judge which bolts to adjust, and how much to adjust each one. On the downside, this type of profile control system is very expensive, and generally requires a high level of technical support. In addition, a deviation is corrected after the fact, so the length of product made prior to a correction is different than after the correction. That length of product may or may not be within specifications.

Another strategy, which is supported by MBraun and others, is to make slot dies without profile control ñboltsò, but to match the internal flow design to the coating liquid and substrate to be coated. Using this approach the dies are machined to an extremely high standard of accuracy and tested to prove that consistent profiles can be achieved. Profiles in production are then measured off-line, for QA requirements.

On the downside, each slot die is limited to some range of coating liquid properties whereas surface tension and viscosity play predominant roles. However a technique of ñbuilding upò a die offline has been developed which utilizes so called shims the operator can exchange. These shims modify the fluid flow inside the die and adjust the die gap width to greatly extend the range of application for a single die.